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# Teaching with Technology

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Classroom teaching is a demanding job. Most people outside education probably think teachers spend most of their time teaching, but teachers are responsible for many tasks that have little to do with classroom instruction. Beyond planning and implementing instruction, teachers are also expected to be managers, psychologists, counselors, custodians, and community "ambassadors," not to mention entertainers. If teaching sounds like an unreasonable, almost impossible, job, perhaps it is.

It is easy to understand how a teacher might become frustrated and disillusioned. Most teachers enter the profession expecting to spark the joy of learning in their students. Unfortunately, the other demands of the classroom are very distracting and consuming. We envision technology as a teacher's liberator to help reestablish the role and value of the individual classroom teacher. To do so, two things must happen. First the perspective of the classroom must change to become learner centered. Second, students and teachers must enter into a collaboration or partnership with technology in order to create a "community" that nurtures, encourages, and supports the learning process (Cognition and Technology Group at Vanderbilt, 1992).

It is important to note that the focus in this chapter is on educational technology as compared to technology in education. There is a difference. Technology in education is often perceived in terms of how many computers or videocassette recorders are in a classroom and how they might be used to support traditional classroom activities, but this is a misleading and potentially dangerous interpretation. It not only places an inappropriate focus on hardware, but fails to consider other potentially useful "idea" technologies resulting from the application of one or more knowledge bases, such as learning theory. Educational technology involves applying ideas from various sources to create the best learning environments possible for students. Educational technologists also ask questions such as how a classroom might change or adapt when a computer is integrated into the curriculum. This integration means that the curriculum and setting may also need to change to meet the opportunities that the technology may offer.

There are four purposes to this chapter. First, we will examine several different stages of technology adoption. Second, we will review traditional roles that technology has served in the classroom. Third, we will examine what a classroom might be like when attention is given to educational technology. Fourth, we will

provide some specific examples that incorporate contemporary educational principles. This chapter will try to present ways in which educational technology may be useful to teachers given current classroom conditions as well as how it might influence the course that many schools may chart in the future.

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## A Model of Technology Adoption in the Classroom

Educational technology is often considered, erroneously, as synonymous with instructional innovation. Technology, by definition, applies current knowledge for some useful purpose. Therefore, technology uses evolving knowledge (whether about a kitchen or a classroom) to adapt and improve the system to which the knowledge applies (such as a kitchen's microwave oven or educational computing). In contrast, innovations represent only change for change sake. Given this distinction, it is easy to argue that educators are correct to resist mere innovation, but they should welcome educational technology. Unfortunately, the history of educational technology does not support this hypothesis (Saettler, 1990).

Although education has witnessed a multitude of both technology and innovation over the past 50 years (Reiser, 1987), the educational system has scarcely changed during that time. Few would argue that doctors and dentists of 50 years ago would be competent and capable enough to practice with the technology of today. Yet, a teacher from 50 years ago would probably feel right at home in most of today's classrooms as most technologies and innovations introduced during this time have been discarded. It is difficult to account for the rapid abandonment of technologies and innovations in education over the past 50 years. Has the educational system reached the point of development where no further improvement can be expected from current educational technology? Have all educational technologies really just been fads of innovation that educators have correctly denounced as irrelevant and unnecessary? We think not in both cases. It seems appropriate to consider these questions as a way to understand both traditional and contemporary roles of educational technology. We will use a simple model as a tool to help explain the patterns of adoption by teachers after they are first introduced to educational technology. Understanding these adoption patterns of the past may give us insights to which technologies may be adopted or discarded in the future.

There have been many attempts to understand patterns of adoption in education (Dalton, 1989; Dwyer, Ringstaff, & Sandholtz, 1991). In this section, we present one such model in simplified form in order to better understand both traditional and contemporary applications of technology in education. The model, as illustrated in Figure 1, has five steps or phases: Familiarization, Utilization, Integration, Reorientation, and Evolution. The full potential of any educational technology can only be realized when educators progress through all five phases, otherwise, the technology will likely be misused or discarded (Rieber & Welliver, 1989; Marcinkiewicz, in press, 1991). The traditional role of technology in education is necessarily limited to the first three phases, whereas contemporary views hold the promise to reach the Evolution phase.

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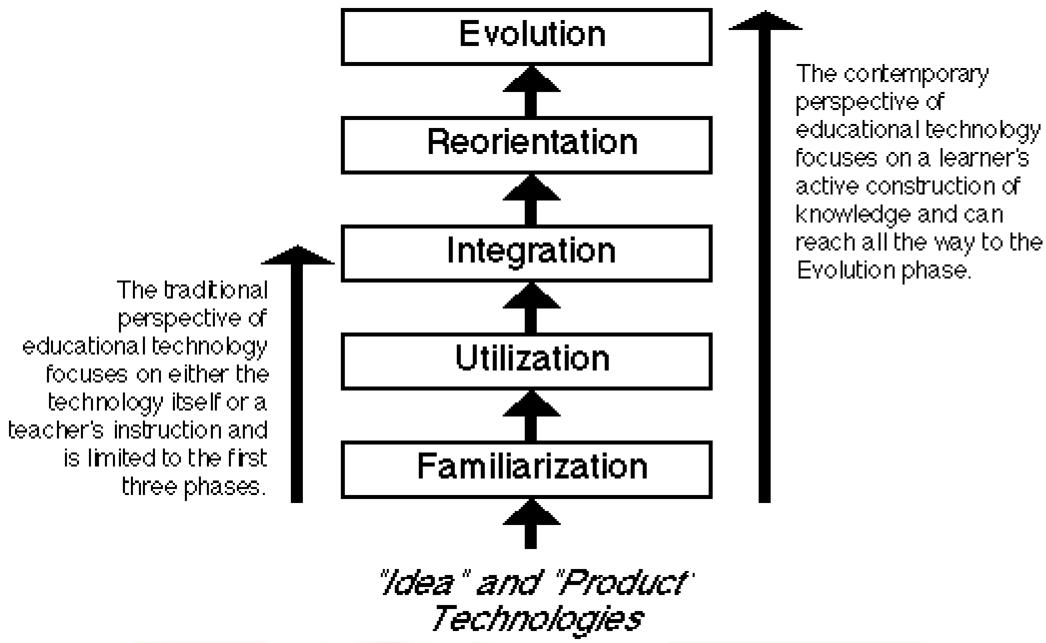


**Figure 1**. A model of adoption of both "idea" and "product" technologies in education.

Click here for an animated version of this model.

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**Familiarization**

The Familiarization phase is concerned with one's initial exposure to and experience with a technology. A typical example of familiarization is a teacher participating in an in-service workshop covering the "how to's" of a technology, such as word processing, spreadsheets, assertive discipline, cooperative learning, motivational strategies, etc. In this phase, the teacher simply becomes acquainted with a technology. Once the workshop ends, so too does the teacher's experience and growth with the technology. All that remains is a memory of the experience. The teacher may discuss the experience and the ideas represented in the experience, even with some degree of authority, but no further action takes place. A great deal of instructional innovation begins and ends with this phase.

**Utilization**

The Utilization phase, in contrast, occurs when the teacher tries out the technology or innovation in the classroom. An example is a social studies teacher who uses role-playing simulations learned in a workshop or graduate course. Obviously, teachers who reach this phase have progressed further than Familiarization, but there is the inherent danger that a teacher will become prematurely satisfied with their limited use of the technology. The attitude of "At least I gave it a try" will likely interfere with any enduring and long-term adoption of the technology. Teachers who progress only to this phase will probably discard the technology at the first sign of trouble because they have made no commitment to it. This is probably the highest phase of adoption reached by most teachers who use contemporary educational media,

including the computer. If the technology were taken away on Monday, hardly anyone would notice on Tuesday.

### Integration

Integration represents the "break through" phase. This occurs when a teacher consciously decides to designate certain tasks and responsibilities to the technology, so, if the technology is suddenly removed or is unavailable, the teacher cannot proceed with the instruction as planned. The most obvious technology that has reached this phase of adoption in education is the book and its derivatives, such as worksheets and other handouts. Most teachers could not function without the support of such print- based technologies. Another example, though perhaps amusing to some, is the chalkboard. Most teachers would find it extremely difficult to teach without it. Hence, the "expendability" of the technology is the most critical attribute or characteristic of this phase (Marcinkiewicz, in press, 1991). Although Integration is the end of the adoption model for many, it really only represents the beginning of understanding educational technology. For some teachers, the Integration phase marks the beginning of a professional "metamorphosis," but only if they progress even further in their adoption pattern.

### Reorientation

The Reorientation phase requires that educators reconsider and reconceptualize the purpose and function of the classroom. It is marked by many characteristics, probably the most important of which is that the focus of the classroom is now centered on a student's learning, as opposed to the teacher's instruction. A teacher who has reached the Reorientation phase does not view good teaching as the delivery of content (i.e. the teaching "acts" of explaining, managing, or motivating). Instead, the teacher's role is to establish a learning environment that supports and facilitates students as they construct and shape their own knowledge. In this phase, the learner becomes the <u>subject</u> rather than the <u>object</u> of education.
Teachers in the Reorientation phase are open to technologies that enable this knowledge construction process and are not threatened by being "replaced" by technology. In fact, these teachers will probably include technology in their classrooms without necessarily feeling the need to be an "expert" themselves. Their interest is on how technology allows their students to engage the subject matter. It would not be unusual for the students to be more competent than their teachers with the technology. For example, consider a history teacher who discovers that students prefer to create HyperCard stacks that replace a traditional term paper assignment (Hoffmeister, 1990). If the teacher has a reoriented view of education that is student-centered, the teacher will focus on how intensely the student has engaged the content, not on how well the stack is "programmed." The teacher will emphasize (and evaluate) how well the student has become both a researcher and explorer due to the availability of the computing tool. Whether the teacher possesses more or less technical skill with HyperCard than the student is inconsequential. In addition, the teacher learns about history and HyperCard along with the student. Of course, the teacher's greater experience is an indispensable resource and guide to the student.
Rather than view a technology as something that must be mastered beforehand and presented to students in a controlled and systematic way, a teacher at the Reorientation phase would encourage and expect students to appropriate the technology in ways that could not be anticipated.

### Evolution

The final phase, Evolution, serves as a reminder that the educational system must continue to evolve and adapt to remain effective. There will never be a final solution

or conclusion and to be searching for one means that one is missing the point. The classroom learning environment should constantly change to meet the challenge and potential provided by new understandings of how people learn. As previously discussed, this appropriate application of basic knowledge for some useful purpose is what defines educational technology and living up to this definition is the hallmark of the Evolution phase.

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## Traditional Role of Technology in Education

There have been two main types of technology in education that we choose to label as "product technologies" and "idea technologies." Product technologies include: 1) hardware, or machine-oriented, technologies that people most often associate with educational technology, such as the range of audio-visual equipment, both traditional (i.e. film strips, movies, audiocassette players/recorders) and contemporary (i.e. videocassette players/recorders, laserdiscs, computers, CD-ROM) and; 2) software technologies, such as print-based material (i.e. books, worksheets, overhead transparencies) and computer software (i.e. computer-assisted instruction). In contrast, idea technologies do not have such tangible forms.

Of course, idea technologies are usually represented in or through some product technology. For example, simulations are, by and large, idea technologies. Simulations try to give people experiences with events and concepts not generally possible (e.g. travel back in time), probable (e.g. ride aboard the space shuttle), or desirable (e.g. the green house effect) under normal conditions. The idea of a simulation must be realized through some product, such as computer software. In this way, the idea is supported or made possible by the product. A classic example of the distinction between product and idea technologies is Henry Ford's assembly line. The concept of the assembly line is an idea technology that transformed industry in the United States. However, the conveyor belts, work stations, and factories that one sees in old photographs show the product technologies that were used to support the original idea.

The distinction between product technologies and idea technologies is important because most of the historical attempts to use technology in education have focused on product technologies, such as teaching machines, educational television and films, and, most currently, computers (Reiser, 1987). Consequently, the role and value of these product technologies were how they supported the established beliefs and practices of classroom teachers. These established practices were largely based on behavioral models which emphasized the transmission and delivery of predetermined content. These approaches exemplify the "student as bucket" metaphor where the emphasis is on "pouring knowledge" into student's minds by designing and delivering well- planned and controlled instruction. Learning is viewed as a consequence of receiving the information. We believe that contemporary notions of educational technology must go well beyond this philosophy of learning and education. Teachers who adopt technologies without considering the belief structure into which these products and ideas are introduced are necessarily limited to the third phase of integration, though, as previously mentioned, few progress that far.

Consider an example of a product technology reaching the integration phase of adoption -- the hand-held graphing calculator. Many high school math teachers use graphing calculators in their teaching. In fact, there are several brands on the market that use a transparent liquid crystal display (LCD) so that the calculator can

be placed on an overhead projector. The use of these calculators easily passes the expendability test for many teachers: Their teaching would be seriously disrupted if the calculators were removed. They would be unable to convey the same information given a quick and sudden return to the static medium of the overhead or chalkboard. However, the degree to which the teacher's instruction has been altered because of the graphing calculator is critical to determining if the teacher is on the verge of entering the Reorientation phase. If the calculator allows the teacher to focus on student's conceptual understanding of the mathematical function, perhaps because of the calculator's ability to draw a graph using real-time animation, then the teacher has begun to rethink and reflect on the partnership between how product and idea technologies can help a student's learning. The teacher will derive satisfaction from how the technology was harnessed to enable and empower students to understand and apply the mathematical ideas. This teacher is on the brink of entering into the Reorientation phase. Such a teacher will probably seek to turn the technology (i.e. the calculator) over to the students for them to begin constructing mathematics.

On the other hand, if the instructional strategies employed by the teacher are virtually the same as those used before the graphing calculator was introduced, then it is very likely that the teacher's adoption of the technology will end with integration since nothing has changed or improved other than the mode of delivery. In this case, although the product technology of the calculator has been integrated, the underlying idea technology of "present, practice, and test" remains unchanged and unchallenged.

The distinction between educators who enter and stall at the Integration phase versus those who are "transformed" and enter the Reorientation phase is best characterized as a magical line on an "instruction/construction" continuum, as illustrated in Figure 2. The utilization and integration of any one technology can be defined by this continuum. The technology of a computer spreadsheet, for example, when used only by a teacher for grade management or as part of an instructional presentation of, say, the principle of averages in a math class, is integrating only the product technology without changing the underlying philosophical base in which it is applied. The philosophical base, in this example, would be an instruction-centered classroom where a teacher manages the presentation and practice of predetermined and preselected content.

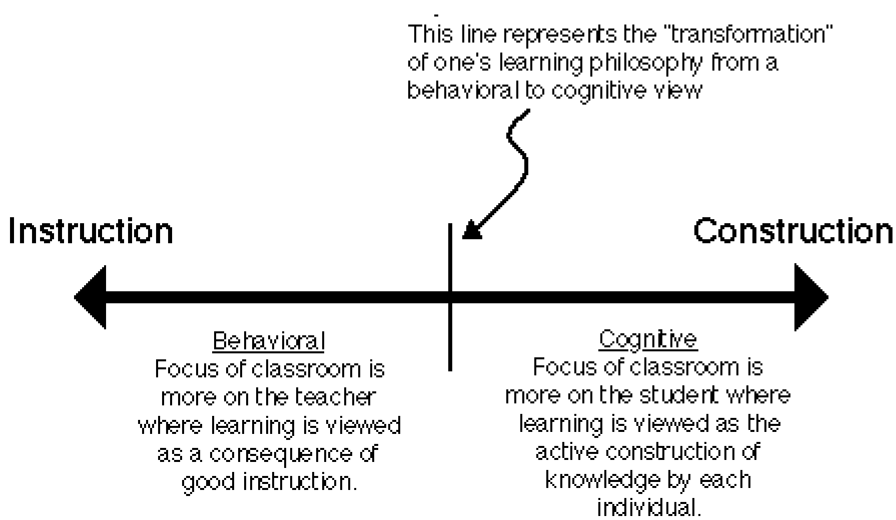


**Figure 2**. Philosophies of learning and teaching can be viewed as a continuum with extreme educational interpretations of behaviorism (for example, instruction) and cognitivism (for example, construction) at either end. Any one educator's philosophy resides somewhere on this line. The threshold between the two views marks a critical point of "transformation" for an educator.

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Consider instead a teacher who uses the same spreadsheet to have students build and construct the knowledge themselves, whether it be the principle of mathematical average or a range of "what if" relationships in economics or history. In this case, the product technology of the spreadsheet is directly supporting the idea technology of a "microworld" where students live and experience the content rather than just study it (Dede, 1987; Papert, 1981; Rieber, 1992).
What are the most fundamental principles of learning that underlie the most contemporary views of idea technologies that will help all educators enter into the Reorientation phase of adoption? This is the goal of the next section.

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## Contemporary Role of Technology in Education

Among many educational goals, three cognitive outcomes are that students should be able to remember, understand, and use information (Perkins, 1992). Apparently, one of these outcomes is very difficult to achieve. After more than a decade of schooling, many students leave school unable to use much of the content they have learned.
Students' inability to apply their learning is attributable to the shallow processing that often occurs in school. Schoolwork often focuses on remembering and organizing lesson content, but rarely on making information meaningful. Meaningful learning is the product of building external connections between existing and new information. Mayer (1984) identified three learning stages that affect meaningfulness: selection, organization, and integration. Information must initially be selected. Selected information must be organized in working memory if it is to be transferred to long term memory. Information that is not organized is meaningless. The nature of the organization determines the degree of meaningfulness. Information that is integrated within familiar knowledge or experiences is more

durable than information that is not associated to prior knowledge. In school, students select information that they memorize and organize sufficiently to enable satisfactory performance on tests, but they often fail to integrate the information by relating it to previous experiences or knowledge stored in long term memory. Consequently, one outcome of education, it seems, is a large reserve of inert information which is eventually forgotten (Cognition and Technology Group at Vanderbilt, 1992). For example, how many of us can remember how to compute the sine of a triangle?

How can teaching with technology facilitate deeper, more meaningful, cognitive processing? Moreover, what framework should be used to inform such decisions? In a sense, teaching with technology is unlikely to differ greatly from teaching in general. Effective technology-based teaching is more likely the result of teachers' abilities to design lessons based upon robust instructional principles than of the technology per se (Savenye, Davidson, & Smith, 1991). Consequently, guidance for designing effective technology-based classrooms should be grounded in the literature on effective pedagogy in general.

Recently, researchers have identified several principles to guide effective teaching (Koschman, Myers, Feltovich, & Barrows, in press). Although designed primarily for instruction in complex and ill-structured domains, the principles are relevant for many instructional tasks. Most real-world tasks are ill-structured. Problems that are "well-structured" generally occur only in classroom settings. In the following section we will examine three principles and consider the implications of each for using technology in the classroom.

**Principle 1: Effective learners actively process lesson content.**

During the past 30 years the shift from behaviorism to cognitivism has modified our conceptions of effective learning and instruction. One of the most consistent themes to emerge from the transition is that learning is an active process. By this it is meant that effective learning requires students to do more than simply respond to stimuli. Instead, learners must actively seek and generate relationships between lesson content and prior knowledge.

One common myth is that product technologies increase interactivity and thereby improve learning. The source of this perception is not difficult to trace. The results of research on students attitudes toward working with product technologies, especially computers, are generally positive (Martin, Heller, & Mahmoud, 1991). Furthermore, research appears to support the belief that product technologies improve learning (Kulik, Bangert, & Williams,1983). Yet, product technologies alone do not ensure learning (Clark,1983). Indeed, in some cases they may detract from learning by diminishing the amount of effort a student invests.

In general, learning requires students to invest considerable mental effort in the task. However, students appear to vary the effort they invest during learning according to their self-perceptions and their beliefs about the difficulty of learning from different media. Salomon (1984) found that children who believed themselves to be effective learners invested greater effort when a learning task was perceived to be challenging than when it was perceived to be easy. However, children with low self efficacy invested greater effort when learning was perceived to be more attainable than challenging. In other words, high ability learners may invest more mental effort in a challenging task, such as reading a book, than in a task perceived to be easy, such as learning from TV. Low ability students may invest more effort in a task they believe to be attainable than one they perceive to be challenging.

We are by no means opponents of product technologies in education. However, we recognize the importance of blending product and idea technologies into "technological partnerships". An example of an effective technological marriage is that of a musical symphony. A good symphony combines an ideal blend of musical instruments (product technologies) and musical compositions (idea technologies). Misusing the capabilities of the instruments or underemphasizing the composition of the musical score will detract from the final production of the symphony. Similarly, effective uses of technology in education require a blend of product and idea technologies. Together, they form environments that unite technological capability with pedagogical necessity -- combining what can be done with what should be done. Too often in education we have failed to find the right blend of technologies. In particular, the capabilities of product technologies are over emphasized. For example, product technologies are often used to increase cost efficiency by replacing the classroom teacher or by transmitting lessons to larger audiences via satellites and telephone lines. Such approaches are often misdirected. Although the importance of increasing access to education should not be devalued, reproducing existing materials is unlikely to improve educational quality. Rather, using technology as delivery media may perpetuate or even exacerbate existing problems. The benefit of technology is not simply its potential to replicate existing educational practice, but its ability to combine idea and product technologies to encourage students to engage in deeper cognitive activity.

**Principle 2: Presenting information from multiple perspectives increases the durability of instruction.**

Although instruction has traditionally focused on learning specific content, much of contemporary curriculum development focuses on solving problems that require learners to develop ever evolving networks of facts, principles, and procedures. The National Council of Teachers of Mathematics (1989), for example, suggested that greater emphasis be placed on solving open-ended "real world" problems in small groups, connecting mathematics with other content areas, and using computer-based tools to allow students to speculate and explore interrelationships among concepts rather than spending time on time-consuming calculations. To achieve such goals, learning should take place in environments that emphasize the interconnectedness of ideas across content domains and help learners to develop flexible networks of propositions and productions (Gagné, 1985). Presenting content from a single perspective is unlikely to reflect the complexity inherent in many concepts. In contrast, repeated exposure to information from varying perspectives helps learners to establish the interrelationships necessary to mediate deep processing and effective retrieval of lesson concepts.

Cooperative learning and hypermedia represent technologies with significant potential for developing multiple perspectives. Cooperative learning is an idea technology that stimulates the development of alternative perspectives through exposure to multiple viewpoints. Two important differences exist between cooperative learning and traditional instruction. First, information to be learned by the students is not transmitted by the teacher. Instead, students teach each each other in small groups of between two and five students. Second, students are made responsible for each other's learning. Students must ensure that every member of their group achieves the lesson's objectives. These experiences appear to benefit students of all abilities. More able students gain from the cognitive restructuring associated with teaching, and less able students benefit from the personalized attention available from group members. Moreover, groups appear to create

environments in which all members benefit from exposure to diverse attitudes and opinions that are often unavailable in the traditional classroom.

Hypermedia is a product technology that represents a shift in beliefs about how information should be presented to and accessed by students. Hypermedia refers to computer programs that organize information nonsequentially. Information is structured around series of nodes that are connected through associative links. Node is the term used to describe an information chunk that is stored in the hypermedia program. Information in a node may be represented through text, illustrations, or sounds. Associative links, which allow users to navigate among nodes, represent the main difference between traditional ways of presenting information on the computer and hypermedia (Jonassen, 1991).

Whereas traditional instruction often presents information sequentially to make the content easier to comprehend, hypermedia allows users to browse through an information base and to construct relationships between personal experience and the lesson. In doing so, it is often claimed, learning becomes more meaningful as students generate webs of semantically and logically related information that accommodate the learners knowledge structure rather than that of the teacher or designer. Although hypermedia environments can be used to present information sequentially to students, when carefully designed, users can create different diverse pathways through a lesson resulting in multiple cognitive representations of the content. By allowing exploration, students are encouraged to discover interrelationships that are often missed in traditional presentations of lesson content and to search for information that meets individual needs. Hypermedia is especially effective when users are encouraged to explore a database, to create links among information nodes, and even to modify a knowledge base based on new insight into content structure (Nelson & Palumbo, 1992).

Hypermedia and cooperative learning represent technologies that can make learning more meaningful. However, both must be managed carefully to achieve the intended outcomes. In cooperative learning, potentially damaging social effects often occur when individual accountability is not maintained. Similarly, hypermedia projects often focus on presenting information and rarely fulfill their promise as knowledge construction kits. Furthermore, although each can be used independently, the learning benefits may be magnified when they are combined. Although many computer lessons are designed for single users, the benefits appear to multiply when used collaboratively (Hooper, 1992).

**Principle 3: Effective instruction should build upon students knowledge and experiences and be grounded in meaningful contexts.**

Philosophical beliefs about how educational goals can best be achieved have shifted from emphasizing curriculum content to focusing on learners' knowledge and experiences (Pea & Gomez, 1992; Tobin & Dawson, 1992). During 1960s and 1970s considerable emphasis was placed on curriculum projects that focused on the structural analysis of content. These projects produced curriculum materials that emphasized helping learners better understand lesson content. For many years, education followed a correspondingly curriculum-centered approach. Teaching focused on analyzing learning tasks and identifying strategies to achieve specific learning outcomes.

Recently, research emphasis has shifted from examining the structure of curriculum materials to determining the cognitive state of the learner. Education is presently concerned less with transmitting the "optimal" structure of lesson content than on building onto the current knowledge level of the student. This perspective has

implications for teaching with technology. First, instruction should attempt to build upon each students experiential base. What a student learns from education is, to a large extent, a function of prior knowledge. One role of technology, therefore, is to bridge personal experiences and formal instruction. Technology should also be sufficiently flexible to adapt to students' on-going instructional needs. One of the hallmarks of a master teacher is the ability to recognize and repair students misunderstandings and misconceptions. When learning difficulties arise, therefore, technology-based instruction should be sufficiently flexible to adapt to students' experiences.

Closely related to building upon students' knowledge and experiences is the belief that instruction should be grounded in familiar contexts. Teachers often decontextualize instruction to stimulate transfer and improve instructional efficiency (Merrill, 1991). Recently, however, researchers have argued that such practices actually hinder transfer. Instead, they claim, instruction should be rooted in real-life problem solving contexts. One such approach, known as situated cognition (Brown, Collins, & Duguid, 1989) involves teaching across multiple contexts before generating rules. Grounding instruction in meaningful contexts appears to have both cognitive and affective benefits. One of the axioms of cognitive psychology is that learning occurs by building upon previously learned experiences. Teaching in familiar contexts appears to help learners to relate new information to those experiences. Contextualization also appears to have a strong motivational component. Learning in a familiar context may make learning more personally relevant than decontextualized learning (Keller & Suzuki, 1988).

Microworlds illustrate how technology can improve meaningfulness by building upon students' experiences and providing a relevant learning environment. A microworld is a special learning environment that accurately models a phenomenon and adapts the complexity of instruction to match the learner's level of understanding. Rieber (1992) designed Space Shuttle Commander, a computer microworld to teach Newton's Laws of Motion. By exploring the microworld, students generate a visceral understanding of the interrelationships that exist among lesson concepts. Microworlds offer opportunities for students to transfer understanding to the real world and to examine and manipulate concepts in a manner that would otherwise be impossible. The microworld contains several difficulty levels to accommodate varying levels of user expertise and introduces an element of fantasy to motivate learners by using the scenario of travelling through frictionless space in a space shuttle.

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## Theory into Practice

In this section we present three examples of educational products that incorporate many of the principles outlined earlier in the chapter. None of these products ensures that learning will take place. The key ingredient in each case is the idea technology employed by the teacher.

**The Jasper Woodbury Problem Solving Series**

The Adventures of Jasper Woodbury (Cognition and Technology Group at Vanderbilt., 1992) is a video package that reflects contemporary beliefs about learning and instruction. Important differences exist between the Jasper series and traditional educational TV. Each episode of the Jasper videos presents instruction in a motivating and realistic environment that encourages students to explore, and to identify and solve real problems. Furthermore, teachers are encouraged to blend

idea technologies such as cooperative grouping and problem-based learning with the videos to make learning active, meaningful, and motivating. Perhaps the most striking difference between the Jasper materials and traditional educational TV concerns the role played by the students. Educational TV often transmits information to students who may, or may not, participate in the learning experience. In contrast, the Jasper series requires students to be actively engaged. While watching the video, students must collect information. Following each episode, a problem is presented. The problem challenges the students to use the information collected during the lesson to identify and solve sub-problems en route to solving the larger problem.

## The Voyage of the Mimi

The Voyage of the Mimi is a multimedia curriculum package developed at the Bank Street College of Education that integrates print, video, and computer materials in learning about science and mathematics. Video is used to present the package's context for learning: a realistic, fictional account of the adventures of the crew of the Mimi, a boat hired by a team of scientists to study humpback whales (a second Mimi series has also been produced using the context of Mayan archaeology). The context was chosen based on research conducted at Bank Street that indicated that people, and especially children, share a general fascination with whales. Mathematics and science become the crew's most important tools as they conduct their whale research or engage in many other problem- solving activities. Video is also used to present a series of documentaries showing real scientists at work using many of the principles introduced in the dramatic episodes. The computer materials provide students with interactive activities, usually simulations and games, that closely mirror the adventures of the Mimi's crew in the video. The print-based materials include a text version of the video and consumable workbooks for the students to complete. The Mimi materials were developed to be sufficiently flexible to provide teachers with multiple entry levels to the materials (Martin, 1987). Teachers can choose to use the materials to augment or to replace all or part of their curriculum. The materials provide for the range of learning outcomes from initial concept formation to problem-solving. The materials can also be used individually by students or cooperatively in groups.

## The Geometric Supposer

The Geometric Supposer (Schwartz & Yerushalmy, 1985a) is a computer-based geometry tool that teaches deductive reasoning by providing students with opportunities to experiment with geometry. Traditionally, geometry teaching has employed passive instructional strategies by focusing on teaching definitions, theorems, and proofs. In contrast, the Geometric Supposer stimulates active learning by encouraging learners to discover geometric properties (Schwartz, 1993). The program allows students to perform two functions that are difficult to achieve in non-computer-based environments. First, it allows students to construct electronically any geometric shape that can be made with a straight edge and a compass. Moreover, the program "remembers" the construction and will repeat the procedure on similar shapes when instructed to do so. Second, the program can automatically measure and report any element of a construction thus allowing users to instantaneously observe the outcomes of any manipulations of the geometric figures. Together, these features allow students to create constructions, hypothesize about geometric relationships, and test and observe the validity of their conjectures. For example, students studying relationships among the medians of a triangle may attempt to identify and test principles by examining results across several different cases (Schwartz & Yerushalmy, 1985b).

**Putting it Together**

It is important to recognize that the learning outcomes achieved using any of the materials outlined above will reflect the idea technology employed. The idea technology will also indicate the level of technology adoption to which the teacher has risen. Three idea technologies have been outlined by the Cognition and Technology Group at Vanderbilt (1992).

1. Basics First advocates mastering basic skills before attempting similar problems embedded in the video. Teachers who use this approach may have entered the Utilization phase, but have not entered the Integration phase. Few instructional differences would result if the videos were removed from the classroom. Similar problems could easily be generated from other sources.
2. Structured Problem Solving involves capitalizing on the design features inherent in the videos, but restricting students' progress to prevent errors and disorientation. For example, teachers might use structured worksheets to guide students' progress. Teachers who focus on rigid lesson structuring may have reached the Integration phase, but probably have not entered into Reorientation.
3. Guided Generation involves using activities that reflect many of the principles outlined earlier in the Chapter. That is, activities that help students to generate meaningful relationships. The teacher focuses on guiding students and exploring issues that may be novel or unfamiliar to both teacher and student. Teachers who use Guided Generation would probably have entered the Reorientation or Evolution adoption phases.

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## Conclusion

In this chapter we have examined why technology has failed to impact education in the past and outlined the conditions necessary for technology to be used effectively in the future. To be used effectively, idea and product technologies must be united and teachers must venture beyond Familiarization and Utilization and into the Integration, Reorientation, and Evolution phases of technology use. Teachers who learn to integrate technology may go on to reconceptualize their roles in the classroom. Guided by research findings from cognitive psychology and other related areas, teachers can create environments in which students actively engage in cognitive partnerships with technology .

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## Discussion Questions

1. How did the high school you attended use technology in the classroom?
2. Describe the characteristics of teachers at each of the levels of technology adoption.
3. Compare and contrast "product" and "idea" technologies. How would you use technology in the classroom?
4. Why has technology consistently failed to impact education?
5. Can technology improve the quality of education? What can be done to help teachers to use technology effectively in the classroom?
6. Describe the teaching traits of a teacher whom you believe to be effective. Where would you place that teacher on the continuum of technology adoption? Explain your decision.

7. How should colleges of education and public school districts help teachers to use technology effectively in their classrooms?

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